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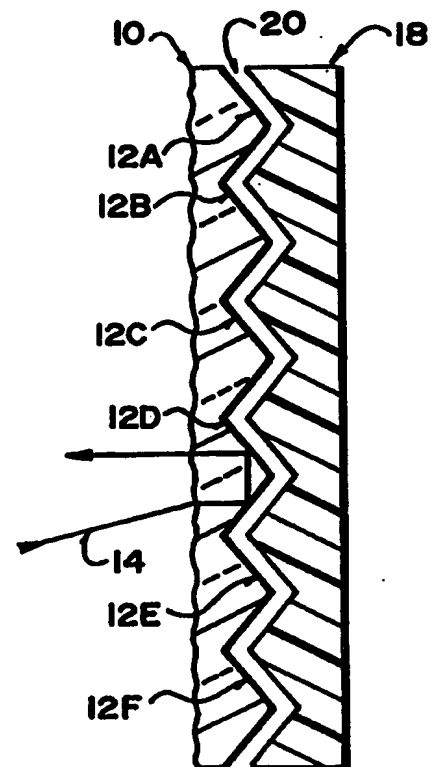
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| (71) Applicant: THE UNIVERSITY OF BRITISH COLUMBIA [CA/CA]; Industry Liaison Office, IRC 331 - 2194 Health Sciences Mall, Vancouver, British Columbia V6T 1Z3 (CA). | | | |
| (72) Inventor: WHITEHEAD, Lorne, A.; 3015 West 12th Avenue, Vancouver, British Columbia V6K 2R4 (CA). | | Published <i>With international search report.</i> | |
| (74) Agent: WIGGS, Blake, R.; Oyen Wiggs Green & Mutala, 480 - 601 West Cordova Street, Vancouver, British Columbia V6B 1G1 (CA). | | | |

(54) Title: **VARIABLE REFLECTIVITY IMAGE DISPLAY DEVICE**

(57) Abstract

A variably reflective display device amenable to multiple pixel display applications. Each pixel has at least one element (10) having a reflective state in which incident light undergoes total internal reflection, and having a non-reflective state in which total internal reflection is prevented. Such prevention is achieved by interfering with (scattering and/or absorbing) the evanescent wave adjacent the surface of the element. For example, a member (18) can be positioned adjacent the element and deformed between first and second positions. In the first position a gap (20) remains between the member and the element to allow the evanescent wave to behave normally. In the second position the member is in optical (but not atomic) contact with the element, such that the member interferes with the evanescent wave and thereby prevents total internal reflection. In one embodiment, each pixel is a grouping of retro-reflective elements (12A, 12B, 12C...) such as corner reflectors. An elastomeric material (18) is provided adjacent each grouping. If a gap (20) is left between the grouping and the elastomeric material, the grouping continues to exhibit total internal reflection. But, if the elastomeric material makes optical contact with the grouping, the evanescent wave is absorbed or scattered and hence total internal reflection is prevented, which in turn prevents reflection of incident light. Thus, the "pixel" formed by the corner reflector grouping is "off" if it makes optical contact with the elastomeric material, and "on" if a gap is left between the two.



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VARIABLE REFLECTIVITY IMAGE DISPLAY DEVICE

Technical Field

5 A display device in which selected, arbitrarily sized
"pixels" are controllably converted from a highly reflect-
tive state arising from the phenomenon of total internal
reflection to a low reflectivity state in which the total
internal reflection phenomenon is disrupted.

10

Background

Corner reflectors (also known as "corner cubes") are
well known reflective devices. As shown in Figure 1, a
light ray incident upon a corner reflector undergoes total
15 internal reflection in each of three separate reflections
at the three perpendicularly opposed facets which form the
corner, with the net result that the light is retro-
reflected from the corner reflector in a direction opposite
to the direction of the incident ray.

20 Miniaturized transparent groupings of corner reflec-
tors, each of which reflectors exhibit the above-described
phenomenon of total internal reflection, are commonly found
in reflective sheeting materials such as 3M Diamond Grade™
reflective sheeting. If the total internal reflection
25 phenomenon could be switched on or off for a group of one
or more corner reflectors, then that group could function
as an image "pixel". An array of such pixels could then be
assembled to construct a display device capable of display-
ing text or images. The present invention achieves this.

30 The prior art has evolved a variety of reflective
image display devices. Examples include non-backlit liquid
crystal display ("LCD") panels like those commonly used in
calculators, and "flip" signs of the type used in some
buses to display route information. However such devices
35 are subject to various shortcomings. For example, LCD
panels typically exhibit less than 50% maximum reflect-
ivity, due to the required front polarizer. Flip signs are
mechanically complex and it is difficult to miniaturize the

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pixels. The present invention is not subject to the same shortcomings.

Summary of Invention

5 The invention provides a multiple pixel image display device. Each pixel has at least one element having a reflective state in which incident light undergoes total internal reflection, and having a non-reflective state in which total internal reflection is prevented.

10 Such prevention is preferably achieved by modifying the evanescent wave associated with total internal reflection. For example, a member can be positioned adjacent the element and deformed between first and second positions. In the first position a gap remains between the member and
15 the element to allow the evanescent wave to have the usual characteristics for total internal reflection, as is well documented in the optics literature. In the second position the member is in optical contact with the element (that is, the gap thickness is substantially less than an
20 optical wavelength), substantially interfering with the evanescent wave, thus preventing total internal reflection.

 Preferably, the member does not make atomic contact with the element when in the second position. Otherwise, substantial difficulty may be encountered in separating the
25 two. Accordingly, the separation distance between the member and the element should be substantially less than one wavelength (about .5 microns) and substantially more than the interatomic spacing of the member or the element (about 10^{-4} microns).

30 In one embodiment, each pixel is a grouping of retro-reflective elements, such as corner reflectors. An elastomeric material is provided adjacent each grouping. If a gap is left between the grouping and the elastomeric material, the grouping continues to exhibit total internal
35 reflection. But, if the elastomeric material makes optical contact with the grouping, the evanescent wave is scattered and/or absorbed and hence total internal reflection is

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prevented, which in turn prevents reflection of incident light. Thus, the "pixel" formed by the corner reflector grouping is "off" if it makes optical contact with the elastomeric material, and "on" if a gap is left between the two.

The invention facilitates construction of both black-on-white and colour displays. In a colour display, each image pixel may for example be a three-faceted corner reflector. By deforming a coloured contact element with respect to a corresponding one of the facets, between first and second positions which respectively do not and do interfere with the evanescent wave at that facet, one may control the spectral distribution of the reflected light.

15 Brief Description of Drawings

Figure 1 is a pictorial illustration of the operation of a prior art corner reflector retro-reflector.

Figure 2A is a cross-sectional illustration of a corner reflector grouping exhibiting high reflectivity due to the phenomenon of total internal reflection.

Figure 2B is a cross-sectional illustration of a corner reflector grouping exhibiting low reflectivity due to prevention of total internal reflection.

Figure 3A is a cross-sectional illustration of a corner reflector showing a contact element consisting of colour dye layer atop a silver substrate spaced from one facet of the corner reflector.

Figure 3B is similar to Figure 3A, but shows the contact element in optical contact with the adjacent facet of the corner reflector to control the spectral distribution of the reflected light.

Description

Figures 2A and 2B depict, in cross-section, a grouping of retro-reflective elements, namely corner reflectors. Only two facets of each corner reflector 12A, 12B, 12C, etc. are visible in such a sectional view, but persons

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skilled in the art will understand that each corner reflector has three perpendicularly opposed facets, as seen in Figure 1. Corner reflector grouping 10 may be a sheet of corner cube film such as that found in 3M Diamond GradeTM reflective sheet film material. There are a variety of possible ways of switching the total internal reflection capability of corner reflector grouping 10 on or off. Before such switching techniques are discussed, it is first useful to review some background principles.

It is well known that light travels at different speeds in different materials. The change of speed results in refraction. The relative refractive index between two materials is given by the speed of an incident light ray divided by the speed of the refracted ray. If the relative refractive index is less than one, then light will be refracted towards the surface, eg light emerging from a glass block into air. At a particular angle of incidence "i", the refraction angle "r" becomes 90° as the light runs along the block's surface. The critical angle "i" can be calculated, as $\sin i = \text{relative refractive index}$. If "i" is made even larger, then all of the light is reflected back inside the glass block and none escapes from the block. This is called total internal reflection. Because refraction only occurs when light changes speed, it is perhaps not surprising that the incident radiation emerges slightly before being totally internally reflected, and hence a slight penetration (roughly one micron) of the interface, called "evanescent wave penetration" occurs. By interfering with (i.e. scattering and/or absorbing) the evanescent wave one may prevent total internal reflection.

It is also useful to consider, by way of background, the case in which grouping 10 is either "on" or "off". For example, in Figure 2A, grouping 10 is "on", such that incident light ray 14 is retro-reflected by corner reflector 12D due to the phenomenon of total internal reflection. Corner reflector grouping 10 thus constitutes a single "pixel" which can, as hereinafter explained, be made to

appear white when "on", due to the high reflectivity exhibited by the corner reflectors. In Figure 2B, corner reflector grouping 10 is "off", such that incident light ray 16 is not reflected by corner reflector 12D due to prevention of the phenomenon of total internal reflection as hereinafter explained. When in the "off" state, grouping 10 can easily be made to appear black, due to the low reflectivity exhibited by the corner reflectors in the off state. An array of such "pixels", each comprising a separate grouping of corner reflectors can accordingly be assembled to form a black on white display capable of displaying text or images.

If corner reflector grouping 10 is to appear white when "on" then grouping 10 should be made somewhat diffuse or a diffuse cover should be positioned over grouping 10. Although it is in practice impossible to make a "perfect" retro-reflector, currently available materials (such as the aforementioned 3M Diamond GradeTM reflective sheeting) have very substantial retro-reflective capability. Accordingly, such materials tend to reflect, to the eye of the observer, only light which has originated from near the eye of the observer, which tends not to be a very bright region. In such a case, the retro-reflector may not appear substantially white. But, if grouping 10 is diffuse, the reflected light is scattered in directions which are sufficiently different from the retro-reflective direction, as is the case with conventional white material, and this therefore achieves a white appearance, without significantly compromising the capability of the device. It should be noted that such diffusion, if too severe, may cause some light rays to travel at angles for which total internal reflection will not occur. This is undesirable, and this problem can be reduced by judicious selection of the level of diffusion and the refractive index of material which forms grouping 10.

One way of switching the total internal reflection capability of corner reflector grouping 10 on or off is to

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mount a sheet of elastomeric film material 18 adjacent the
rear surface of corner reflector grouping 10, as seen in
Figures 2A and 2B. In Figure 2A, a small gap 20 is left
between the adjacent faces of the sheet film materials
5 comprising corner reflector grouping 10 and elastomeric
sheet 18. With gap 20 present, elastomeric sheet 18 has no
effect on corner reflector grouping 10. This is because
gap 20 is much larger than one micron and therefore does
not interfere with the evanescent wave and hence does not
10 prevent the total internal reflection capability of corner
reflector grouping 10. Thus, the "pixel" formed by corner
reflector grouping 10 is "on" if gap 20 is present.

However, in Figure 2B, control means 19 has been
activated to move elastomeric sheet 18 in the direction of
15 arrow 21 such that the adjacent faces of corner reflector
grouping 10 and elastomeric sheet 18 are in "optical
contact" with one another. Optical contact between
elastomeric sheet 18 and corner reflector grouping 10
brings elastomeric sheet 18 substantially closer than one
20 micron to corner reflector grouping 10, thereby scattering
and/or absorbing the evanescent wave adjacent corner
reflector grouping 10, thus preventing the capability of
corner reflector grouping 10 to totally internally reflect
incident light ray 16. The "pixel" formed by corner
25 reflector grouping 10 is accordingly "off" if the adjacent
faces of corner reflector grouping 10 and elastomeric sheet
18 are in optical contact with one another, with no gap
between them.

Control means 19 may be any one of a large possible
30 range of means capable of displacing elastomeric sheet 18
through the small displacements required to either form gap
20 or to achieve optical contact between elastomeric sheet
18 and corner reflector grouping 10. For example, control
means 19 may be a hydraulic or pneumatic actuator; or, an
35 electronic, electrostatic, magnetic, magnetostrictive or
piezoelectric transducer, etc.

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The elastomeric characteristic of sheet 18 is important. If a stiff, non-elastomeric material were substituted for sheet 18 then the surfaces of both corner reflector grouping 10 and sheet 18 would have to be made flat to within about one tenth of one wavelength to enable the surfaces to be brought into optical contact with one another so as to interfere with the evanescent wave and thereby prevent total internal reflection. Attainment of such flatness is impractically expensive. Even if surfaces exhibiting such flatness were readily and inexpensively available, the presence of minute foreign particles between corner reflector grouping 10 and sheet 18 could prevent attainment of optical contact between the surfaces over a large area which would therefore remain totally internally reflective. Due to its elastomeric characteristic, sheet 18 is able to attain optical contact with substantially the entire adjacent portion of corner reflector grouping 10, with minute foreign particles preventing attainment of optical contact in only relatively insignificantly small areas.

Preferably, elastomeric sheet 18 has a thin, comparatively hard (that is, hard in comparison to the soft elastomeric material) outer surface coating which prevents substantial atomic contact between sheet 18 and corner reflector grouping 10, but does not prevent optical contact between the two surfaces as aforesaid. If such atomic contact occurs, substantial force and time may be required to separate the two surfaces when it is desired to switch the pixel from "off" to "on". In order to achieve the required deformation of elastomeric sheet 18 necessary to attain optical contact with corner reflector grouping 10 (especially if the face of elastomeric sheet 18 is not contoured to match the adjacent corner reflector contoured face of corner reflector grouping 10) it is advantageous to form elastomeric sheet 18 of a low modulus elastomeric substance, such as are typically called "silicone gels".

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It will thus be understood that the separation distance between the two surfaces must be substantially less than one wavelength (about .5 microns) in order to attain optical contact between the surfaces; and, substantially greater than the materials' typical interatomic spacings (about 10^{-4} microns) in order to prevent atomic contact between the surfaces.

It will also be understood that if micro-miniaturization techniques are employed one may avoid the need for elastomeric sheet 18 and substitute some non-elastomeric material. Specifically, if the individual corner reflectors contained within corner reflector grouping 10 are sufficiently small, then the material's large scale surface flatness becomes less important.

For each "pixel", an electronically controlled pneumatic actuator (not shown) may be provided to deform elastomeric sheet 18 between a first position in which gap 20 remains between corner reflector grouping 10 and elastomeric sheet 18, and a second position in which elastomeric sheet 18 is in optical contact with corner reflector grouping 10.

As depicted in Figures 2A and 2B the face of elastomeric sheet 18 is contoured to match the adjacent corner reflector contoured face of the sheet material comprising corner reflector grouping 10. However, such contour matching is not essential. If corner reflectors 12A, 12B, 12C, etc. are sufficiently small, then elastomeric sheet 18 could simply be deformed under applied electrostatic pressure to force elastomeric sheet 18 into the desired optical contact with corner reflector grouping 10 whenever corner reflector grouping 10 was to be switched "off".

By making the applied electrostatic pressure slightly less than that required to achieve optical contact between elastomeric sheet 18 and corner reflector grouping 10, one could adapt the device to function as a "white board". Specifically, optical contact between elastomeric sheet 18

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and corner reflector grouping 10 would occur only at those regions where additional pressure was applied by bringing a "writing implement" such as a stylus into contact with a desired point on the outward face of corner reflector grouping 10, thereby turning the contacted pixel(s) off and converting their appearance from white to black. The "white board" could be erased by removing the voltage signal used to apply the initial electrostatic pressure. The location of the pixel(s) contacted by the stylus could easily be sensed, thus additionally allowing the device to function as a digitizer for converting an image to electronic form.

As explained above, a light ray incident upon a corner reflector undergoes total internal reflection by making three separate reflections at the three perpendicularly opposed facets which form the corner reflector. Accordingly, for each corner reflector within grouping 10, there are three separate opportunities for preventing total internal reflection. By independently controlling light reflection at each of the three opposed facets of each corner reflector, one may construct a full colour display.

For example, instead of employing a single elastomeric sheet 18, one may alternatively provide a different contact element for each one of the three opposed facets of each corner reflector, with the contact elements respectively consisting of yellow, magenta, and cyan dyes layer atop a silver substrate. Figure 3A depicts, in cross-section, a single corner reflector 24 with a contact element 28 spaced from one facet 29 of corner reflector 24 by a gap 26. The face of contact element 28 adjacent facet 29 consists of a colour dye layer 32 atop a reflective silver substrate 30. For ease of illustration, only one contact element is shown, but in practice a separate contact element is associated with each of the three facets of corner reflector 24.

With gap 26 present, corner reflector 24 exhibits total internal reflection, resulting in retro-reflection of

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incident ray 22 as described above. However, if gap 26 is eliminated by placing contact element 28 in optical contact with facet 29 as shown in Figure 3B, then contact element 28 interferes with the evanescent wave as explained above.

5 In such case, dye layer 32 selectively absorbs certain wavelengths, with the degree of absorption depending upon the degree of optical contact between contact element 28 and facet 29 (achievable by controllably positioning contact element 28 adjacent facet 29 in any one of a selected

10 range of optical contact sub-positions). As light passes through dye layer 32 to reflective silver substrate 30, the light undergoes primary colour subtraction (i.e. the yellow dye layer absorbs blue light, etc.). Accordingly, one may control the spectral distribution of the reflected ray 34

15 by controllably sub-positioning the respective contact elements as aforesaid to achieve full colour display.

Moreover, the colour display described above can achieve a high reflectivity, in contrast to the very low maximum reflectivity of prior art colour displays. This is

20 because, when any particular corner reflector facet is "on" (i.e. no contact element is in optical contact with the corner reflector facet) that facet remains fully reflective and can easily be made to appear white in the same manner described above for a black on white display. (By con-

25 trast, prior art colour displays which have separately coloured red, green and blue pixels have substantially reduced reflectivity when the pixel is not activated so as to give the pixel a non-coloured net appearance.) In accordance with the present invention, if all three of a

30 given corner reflector's facets are "on", that corner reflector appears white. If one or two, but not all three of a given corner reflector's facets are "on" then that corner reflector has a coloured appearance, with the colour depending upon the degree of optical contact between the

35 contact elements and their corresponding "off" corner reflector facets.

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Alternatively, one may construct a colour display in the more common fashion of segmenting each pixel into red, blue and green segments. By selectively optically contacting suitable members with each of the respective segments, one may interfere with the evanescent wave at the respective segments to a degree sufficient to alter the spectral distribution of the light reflected through the respective segments and thereby give the overall pixel any desired colour. However, this "segmented" method cannot yield a bright white appearance in the uncoloured state.

Another, less sophisticated colour technique involves applying a colour "A" to the material of sheet 10, and applying a different colour "B" to the material of elastomeric backing 18. In this case, the "on" state is represented by colour "A", and the "off" state is represented by colour "B" combined subtractively with colour "A". Useful examples of "A" - "B" colour combinations include yellow-black, yellow-red, yellow-green, magenta-black, magenta-red, magenta-blue, cyan-black, cyan-green, cyan-blue, white-yellow, white-cyan, white-magenta, white-red, white-green, white-blue and white-black. For example, the white-green combination is of interest in relation to highway signs, which typically feature white lettering on a green background (the "on" state may represent either a background or a foreground colour).

It is noteworthy that the overall grouping 10 need not be miniature. For example, if a highway sign or sports stadium type large format display is required, then the single "pixel" formed by corner reflector grouping 10 could be several inches square, or even larger. Besides simplifying construction of the above-described contact elements, this also simplifies the circuitry required to control a complete sign consisting of a large array of such pixels. For example, in some large format prior art displays, each pixel must be formed of a relatively large number of light sources, with each such source requiring separate power and control circuitry. By contrast, the

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present invention incorporates display pixels which require no such pixel-size-dependent multiplication of power or control circuitry. The invention accordingly facilitates construction of large, low pixel cost per unit area, efficient, bright displays. Besides the aforementioned highway sign or sports stadium applications, the invention is also easily adapted to the construction of advertising displays, variable message signs, clocks, and the like.

As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. For example, a variety of structures exhibiting the phenomenon of total internal reflection could be used in place of corner reflectors, as long as sufficient reflection occurs. As another example, in some applications of the invention, such as highway signs, the above-described retro-reflective property is important (i.e. to achieve directed reflection of light emitted by vehicle headlamps to illuminate the sign for viewing by persons in such vehicles), but in most other applications only the reflection effect is wanted in which case the outward face or optical material of the sheet comprising corner reflector grouping 10 should be somewhat diffuse. Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.

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WHAT IS CLAIMED IS:

1. An image display device (10) characterized by a reflective state in which incident light undergoes total internal reflection and a non-reflective state
5 in which said total internal reflection is prevented, and comprising means (19) for controllably switching between said states.
2. A multiple pixel image display device (10), character-
10 ized by each of said pixels comprising at least one element (12A, 12B, 12C, ...) having a reflective state in which incident light undergoes total internal reflection and a non-reflective state in which said total internal reflection is prevented, said device
15 further comprising means (19) for controllably switching said elements between said states.
3. An image display device as defined in claim 2, wherein
20 said total internal reflection is further characterized by an evanescent wave adjacent a surface of said element, said prevention further comprising interfering with said evanescent wave.
4. An image display device as defined in claim 2, wherein
25 said total internal reflection is further characterized by an evanescent wave adjacent a surface of said element, said switching means further comprising a member (18) positioned adjacent said element and deformable between a first position in which a gap
30 (20) remains between said member and said element and a second position in which said member is in optical contact with said element, said member not interfering with said evanescent wave in said first position, said member interfering with said evanescent wave in said
35 second position and thereby preventing said total internal reflection.

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5. An image display device as defined in claim 4, wherein said second position does not permit substantial atomic contact between said member and said element.
- 5 6. An image display device as defined in claim 4, wherein said optical contact further comprises a separation distance between said member and said element of substantially less than one wavelength, substantially more than typical interatomic spacing, and substan-
10 tially more than said element's interatomic spacing.
7. An image display device as defined in claim 4, wherein said optical contact further comprises a separation distance between said member and said element of
15 substantially less than .5 microns and substantially more than 10^{-4} microns.
8. An image display device as defined in claim 2, wherein each of said elements is retro-reflective, and wherein
20 each of said pixels further comprises a grouping of said elements.
9. An image display device as defined in claim 8, wherein said retro-reflective elements are corner reflectors.
25
10. An image display device as defined in claim 8, wherein said retro-reflective element grouping is diffuse.
11. An image display device as defined in claim 3, further
30 comprising, for each one of said pixels, an elastomeric material (18) adjacent said retro-reflective element grouping, said elastomeric material deformable between a first position in which a gap (20) remains between said grouping of retro-reflective elements and
35 said elastomeric material, and a second position in which said elastomeric material is in optical contact with said retro-reflective element grouping.

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12. An image display device as defined in claim 11, wherein said elastomeric material has a thin, comparatively hard outer surface coating.
- 5 13. An image display device as defined in claim 2, each of said pixels comprising at least one three-faceted corner reflector (24), said image display device further comprising a coloured reflective contact element (28) for each one of said three corner reflector facets (29), each one of said contact elements
10 deformable between a first position in which a gap (26) remains between said one contact element and said corresponding corner reflector facet, and a second position in which said one contact element is in
15 optical contact with said corresponding corner reflector facet.
14. An image display method, characterized by the steps of:
- 20 a. forming a plurality of image pixels, each of said pixels having a reflective state in which incident light undergoes total internal reflection; and,
- b. preventing said total internal reflection at
25 selected ones of said pixels to switch said selected pixels from said reflective state to a non-reflective state.
15. An image display method as defined in claim 14,
30 wherein said total internal reflection is further characterized by an evanescent wave adjacent a surface of said respective pixels, and said preventing step further comprises interfering with said evanescent wave at said selected pixels.
- 35 16. An image display method as defined in claim 14, wherein said total internal reflection is further

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characterized by an evanescent wave adjacent a surface of said respective pixels, and wherein said preventing step further comprises, for each of said pixels, positioning a member adjacent said respective pixels and deforming said member between a first position in which a gap remains between said member and said pixel, and a second position in which said member is in optical contact with said pixel, said member not interfering with said evanescent wave in said first position, said member interfering with said evanescent wave in said second position and thereby preventing said total internal reflection.

17. An image display method as defined in claim 16, wherein said second position does not permit substantial atomic contact between said member and said pixel.

18. An image display method as defined in claim 16, wherein said step of deforming said member into said second position further comprises positioning said member at a separation distance from said pixel substantially less than one wavelength and substantially more than typical interatomic spacing and substantially more than said pixel's interatomic spacing.

19. An image display method as defined in claim 16, wherein said step of deforming said member into said second position further comprises positioning said member at a separation distance between said member and said pixel of substantially less than .5 microns and substantially more than 10^{-4} microns.

20. An image display method as defined in claim 14, wherein said total internal reflection is further characterized by an evanescent wave adjacent a surface

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of said respective pixels, and said preventing step further comprises, for each one of said selected pixels, deforming an elastomeric material between first and second positions which respectively do not and do interfere with said evanescent wave at said selected pixels.

21. An image display method as defined in claim 14, wherein said image pixels each comprise a three-faceted corner reflector, said preventing step further comprising, for each one of said pixels, deforming a coloured contact element with respect to a corresponding one of said facets between first and second positions which respectively do not and do interfere with said evanescent wave at said corresponding facet.

22. An image display method as defined in claim 14, wherein said image pixels each comprise a red, blue and green segments, said preventing step further comprising, for each one of said segments, deforming a contact element with respect to a corresponding one of said segments between first and second positions which respectively do not and do interfere with said evanescent wave at said corresponding segment.

FIG. 1A

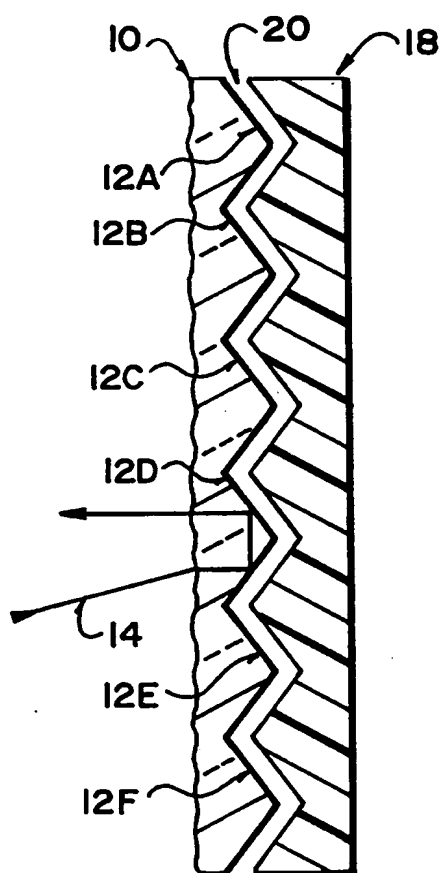
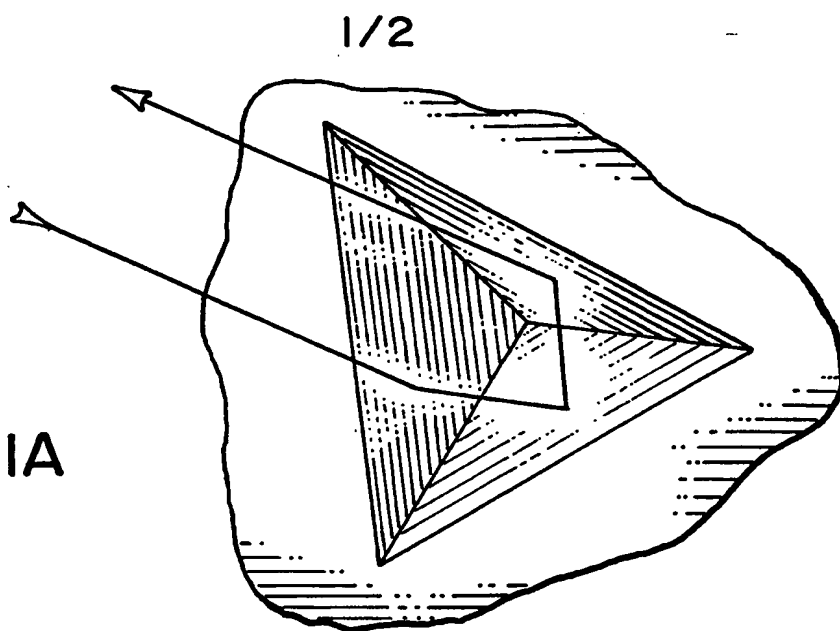


FIG. 2A

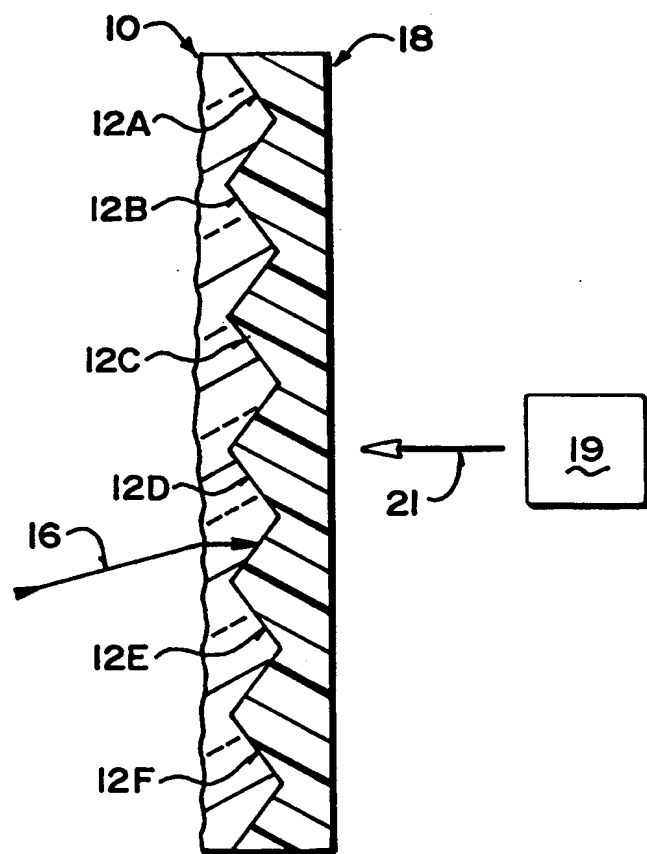


FIG. 2B

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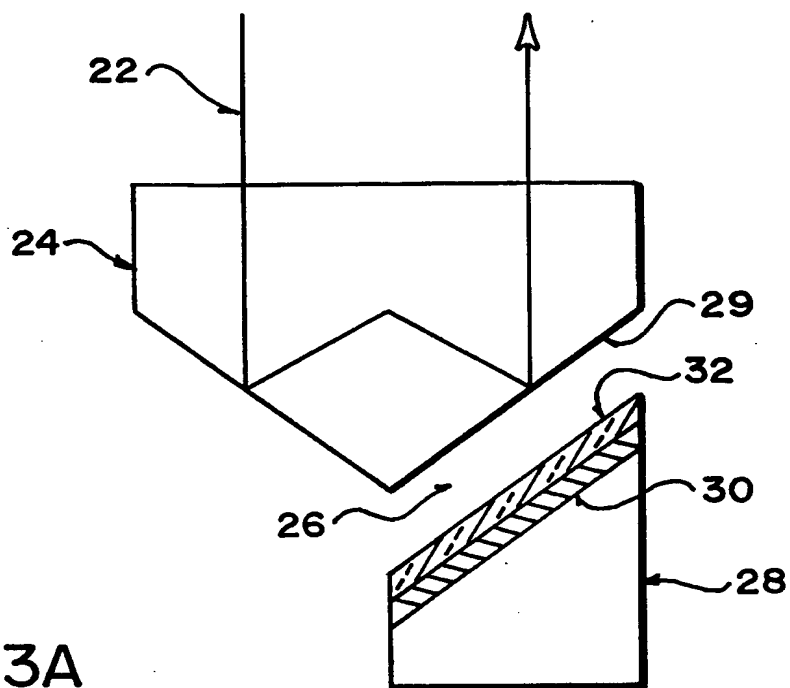


FIG. 3A

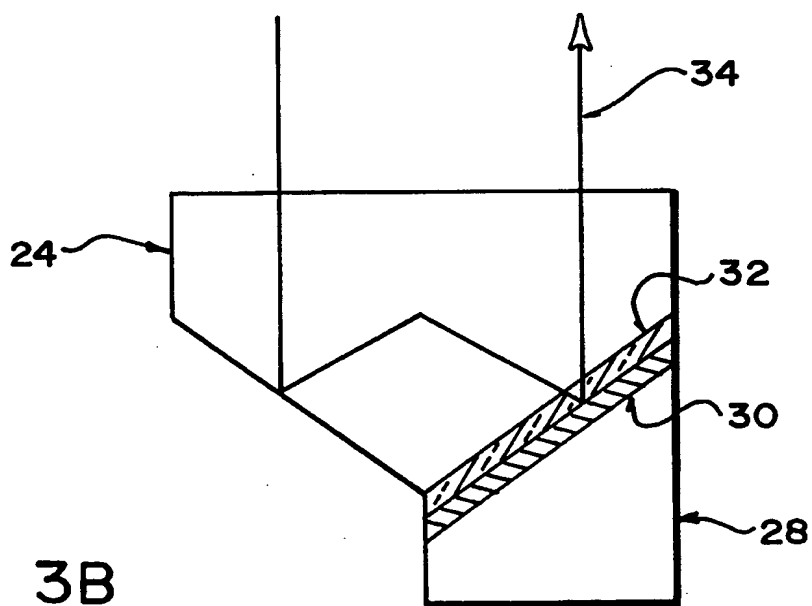


FIG. 3B

INTERNATIONAL SEARCH REPORT

International Application No

PCT/CA 98/00458

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02B26/02 G09F9/37

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G02B G09F G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|----------|---|-----------------------|
| X | DE 43 43 808 A (DEUTSCHE THOMSON-BRANDT) 29 June 1995 see column 3, line 03 - line 12; figure 6 | 1-12, 14-20 |
| A | see column 3, line 13 - line 18 --- | 13, 21, 22 |
| X | US 3 987 668 A (POPENOE) 26 October 1976 see column 2, line 59 - column 6, line 23; figures 2, 3 --- | 1 |
| A | US 3 730 608 A (CASTEGNIER) 1 May 1973 see column 2, line 58 - column 3, line 36; figures 3, 4 --- | 1-22 |
| A | US 3 698 793 A (TELLERMAN) 17 October 1972 see column 3, line 05 - column 5, line 29; figure 3 ----- | 1 |



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

21 July 1998

Date of mailing of the international search report

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Diot, P

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/CA 98/00458

| Patent document cited in search report | | Publication date | Patent family member(s) | Publication date |
|---|---|---------------------|----------------------------|---------------------|
| DE 4343808 | A | 29-06-1995 | NONE | |
| US 3987668 | A | 26-10-1976 | NONE | |
| US 3730608 | A | 01-05-1973 | NONE | |
| US 3698793 | A | 17-10-1972 | NONE | |